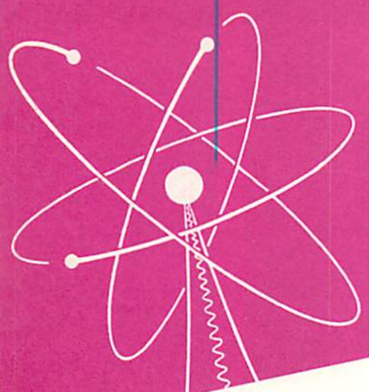

COLOR SYNC CIRCUITS

Lesson T4E-10A

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

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T4E-10A

COLOR SYNC CIRCUITS

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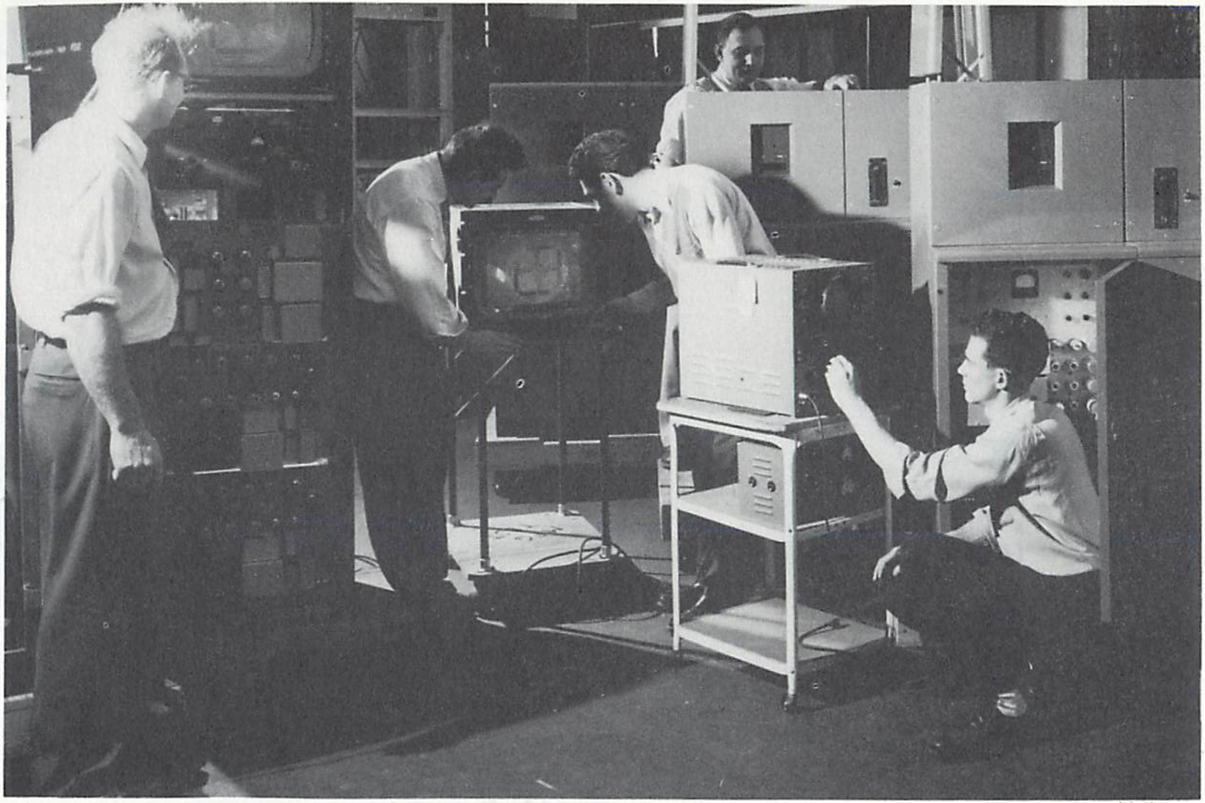

As shown here, similar test instruments are used to make operation checks of both monochrome and color equipment. Operation checks are being made by color slide and film pickup equipment (at right).

Courtesy Allen B. DuMont Laboratories, Inc.

COLOR SYNC CIRCUITS

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A great deal of the joy of life consists in doing perfectly, or at least to the best of one's ability, everything which he attempts to do. There is a sense of satisfaction, a pride in surveying such a work—a work which is rounded, full, exact, complete in all its parts—which the superficial man, who leaves his work in a slovenly, slipshod, half-finished condition, can never know. It is this conscientious completeness which turns work into art. The smallest thing, well done, becomes artistic.

—William Mathews

COLOR SYNC CIRCUITS

In the television broadcast studio, the scene is focused on the pickup tube in the color camera. The variations of the light, shade, and color in the scene are converted to electric pulses by scanning the mosaic, or target area, with an electron beam. As in monochrome television, the scanning beam moving across the target picks up the picture elements one at a time in sequence. This information is carried through the transmitter in the same order, and then radiated from the antenna.

At the receiver, an image of the original scene is reproduced on the picture tube screen. The picture is "painted" on the screen by the electron beam which is modulated with the transmitted information. However, in order to obtain a true image, each element of the picture must appear in the order that pickup occurs. That is, the scanning beam in both the camera tube and picture tube must move across the scanning area at the same relative time.

When the two beams are moving across their respective scanning areas at the same time they are synchronized. Just like black and white television, the control of synchronism between the camera and the receiver is provided by the sync pulses generated at the studio. These pulses are carried to the camera by transmission lines and are added to the composite video signal radiated by the transmitter.

In addition to these sync pulses, which control the sweep circuits of the receiver, a color sync signal must be transmitted to control the color of the picture elements. The portion of the composite wave-form which carries the color information is independent of the signal which carries the brightness information, and therefore, it requires separate control.

The composite video wave for color transmission consists of the following components: The luminance information which determines the brightness of picture elements; the sweep sync signal which properly locates the picture elements in the reproduced image; the chrominance information which carries the hue and saturation information; and color sync signal which makes sure the correct hue and saturation information is detected.

Essentially the difference between a black and white and color TV receiver, not considering the picture tube, is the addition of a chrominance section. Within the chrominance section two major events happen to the transmitted signal. First, the color information present in this signal is synchronized with that of the transmitter and secondly, once the synchronization is settled, the I and Q or the B-Y and R-Y signals are demodulated. Having finished color demodulation in a previous lesson, we are now in a position to examine the necessary color sync circuits which will produce the desired demodulator voltages. At this point, a brief review of the transmitted signal will show a need for this color synchronization.

NEED FOR COLOR SYNCHRONIZATION

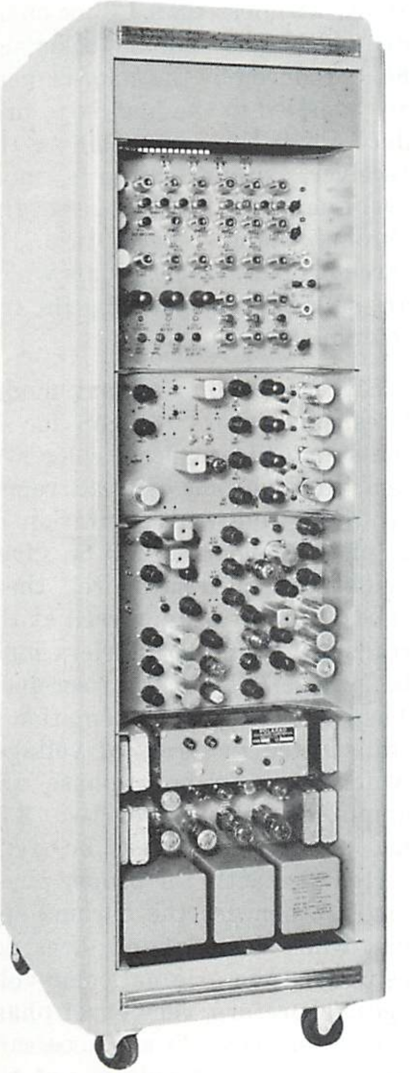
The transmission system connecting the camera and picture tube must carry the information representing the red, green, and blue primary colors in the scene to be reproduced. These three colors are not transmitted as separate signals to operate a receiver. For compatibility, a signal arrangement is required which provides a brightness component designed to operate a black-and-white receiver. Furthermore, the transmission of these three separate signals does not make the most efficient use of the television channel.

To use the 6 mc channel efficiently, three new signals are transmitted: a brightness component "Y" which occupies the major portion of the channel width, and two chroma signals I and Q with less than 1.3 mc channel width. The primary color signals produced by the color camera are sampled in the matrix to produce these three signals. At the receiver, similar circuits must reconvert the brightness and chroma signals back into the three primary color signals which are suitable for operating the tri-color picture tube.

Since a chroma signal modulates subcarriers at 3.58 mc in the standard broadcast color system, the chroma signal represents the hue and saturation of a picture element for a given brightness. Furthermore, these subcarriers are suppressed at the transmitter and so carriers must be reinserted at the receiver. The chroma signal information is transmitted in terms of voltages which vary in both phase and amplitude. Therefore, two 3.58 mc subcarriers must be reinserted at exactly the proper phase angle, otherwise the chroma signal, when demodulated, does not reproduce the original color voltages. Therefore, very exact phase controlling circuits are necessary to assure correct voltages at the output of the demodulators.

PHASE CONTROL CIRCUITS

Two types of 3.58 mc phase control circuits are popular in color TV receivers. The automatic phase control (apc) circuit shown



This color bar generator provides a video signal for test purposes. The third panel from the top controls the color burst and sweep sync signals.
Courtesy Polarad Electronics Corp.

in Figure 1A is used more commonly of the two. The second type has a crystal ringing circuit as shown in Figure 1B.

In the standard broadcast color television signal, the hue is transmitted as phase modulation of a subcarrier. The saturation of the color for a given luminance is provided by amplitude modulation. In order for the receiver to detect the phase of the chroma signals, a reference signal must be supplied at the receiver. A local 3.579545 mc sampling oscillator is used for this purpose.

To make sure that this local subcarrier oscillator has the same phase and frequency as the transmitter oscillator, a color burst is transmitted at the subcarrier frequency during line retrace interval to synchronize the local oscillator. By means of this burst, the color sync circuits in the receiver control the phase of the reinserted subcarrier.

For both Figures 1A and 1B, the color sync circuit is in operation, that is, chrominance information passes through it only when the 3.58 mc burst is present on the back porch of the sync pulse. The output from the block labelled "color killer" in each circuit is zero allowing the color demodulators or band-pass amplifier to perform their action for color signals. However, for black and white reception, the output of the color killer in both phase control circuits is such that the controlled stages are cut off. Thus, the luminance voltage E_Y'

cannot enter the demodulators to cause any color interference whatsoever. Also the burst amplifier is off so that the luminance voltage E_Y' cannot enter the sync section.

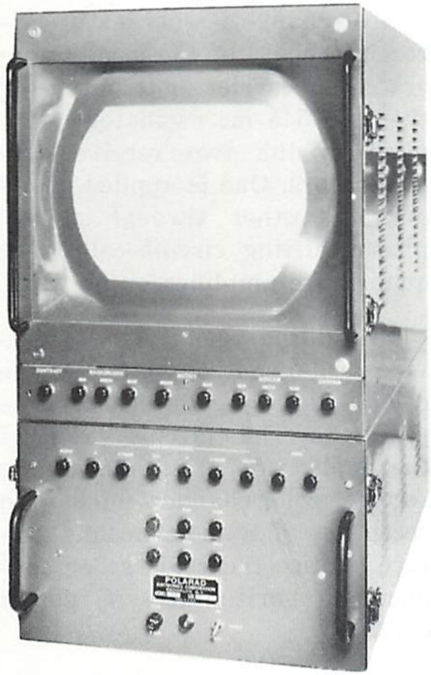
Two signals are applied to the burst amplifier. The color burst is supplied by the 1st video amplifier and the gating pulse is taken from horizontal deflection circuits. To prevent video frequencies near 3.58 mc from entering the phase detector circuits, the burst amplifier normally is biased to cutoff. Only when a color burst arrives, does the gating pulse applied to the stage cause conduction. Therefore only the color burst is amplified and applied to the next stage.

In Figure 1A the phase detectors receive a second signal from the local 3.58 mc sampling oscillator through the color phase (or buffer) amplifier. A variable adjustment in this amplifier is provided to assure a correct final reference phase of the oscillator output in the wide band chrominance receiver. The phase of the color burst is compared to the output of the color phase amplifier to determine the d-c control voltage which is applied to the reactance tube. The magnitude and polarity of this control voltage is proportional to the degree and direction of oscillator phase shift.

The reactance presented to the oscillator by the reactance tube is determined by its normal operating bias. Any change in this bias by the d-c control voltage changes its reactance and, in turn, the frequency and phase of the oscillator output. The direction of change is such as to correct the phase of the locally generated subcarrier. The output of the 3.579545 mc oscillator is applied to the two receiver demodulators. One is applied direct and the other through a 90° phase shifting circuit called the quadrature amplifier or network.

In addition, the apc circuit provides a d-c control voltage to the color killer stage used in some receivers. This circuit prevents the application of signals to the receiver color channels during the reception of a monochrome picture. Notice the color killer conducts on horizontal sync pulses only.

In the second type of color sync circuit of Figure 1B, the same two inputs are provided to the burst amplifier. Since the 3.58 mc burst is all that is passed through the amplifier, it is applied to a crystal ringing circuit. Essentially, the crystal ringing circuit is a high-Q circuit, including a crystal resonant to only one frequency, in this instance 3.58 mc. When the burst is applied to the circuit, it causes the circuit to oscillate or "ring", being of the proper phase due to the burst itself. This properly phased reference voltage is then applied to an amplifier. The amplifier output provides a sufficiently large signal so that its amplitude is controlled to a desired level by the limiter. This allows a constant amplitude reference voltage, free from noise peaks, and assures proper demodulation. To provide proper low impedance matching into the demodulators, a cathode follower is used. In addition, the quadrature network is the second cathode follower. Since the output of the 3.58 mc limiter is not large enough, a voltage doubler labelled "color killer doubler" precedes the color killer stage. Again notice that the color killer stage is gated and conducts only on every horizontal sync pulse.



The color TV video monitor is used to check the quality of NTSC signals in the studio.
Courtesy Polarad Electronics Corp.

Each of the stages of these two major types of color sync sections needs to be described in detail. First, let's consider the stages of the apc system for both narrow and wide band chrominance receivers. There are a few minor differences in the apc system for a wide band as compared to a narrow band chrominance receiver, but none of these affect the block diagram of Figure 1A.

Gated Burst Amplifier

The phasing accuracy of the apc system depends on the information contained in the color burst. To prevent other frequencies contained in the composite video signal from affecting the phase of the subcarrier oscillator, the burst is separated from the video signal by the gated burst amplifier. The circuit diagram of this amplifier as used in a wide band chrominance receiver is shown in Figure 2A. Figure 2B is the narrow band receiver circuit.

In Figure 2A, color bursts are coupled inductively to the burst amplifier V_1 by transformer T_1

secondary which is tuned to 3.58 mc. The primary of T_1, not shown, is located in the plate circuit of the video amplifier. In order to amplify only the burst, V_1 is allowed to conduct only during the time the burst is present at the grid.

The amplifier V_1 is biased to cutoff by a fixed positive voltage applied to the cathode by the voltage divider R_3R_4 connected across the power supply. R_3 is bypassed by capacitor C_4 to prevent a change in bias during the time a gating pulse is applied to the cathode.

During the horizontal blanking interval a negative pulse is applied to the cathode of V_1 from transformer T_2. This is a secondary winding on the horizontal output transformer. The flyback pulse which is applied to the cathode is wide enough to allow the tube to pass the 8 to 10 cycles of the color burst. The C_4R_3 network is an integrator which delays the gating pulse so that the burst amplifier conducts during the precise time interval that the burst is present at the grid. Amplified in the plate circuit, the color burst is transformer coupled to the phase detectors by T_3.

In the narrow band chrominance circuit of Figure 2B, the operation of the burst amplifier is somewhat the same. A signal from the bandpass amplifier enters L_1 through T_1. L_1C_1 are tuned to 3.58 mc forming a parallel resonant circuit. When the horizontal sync gating pulse at T_2 raises the voltage on the screen grid, the color burst signal is amplified by stage V_1. R_3C_3 provides the necessary time delay for this pulse to drive the tube into conduction exactly when the burst is present. Transformer T_3 is tuned to 3.58 mc and its output is applied to the phase detectors. Therefore, without the burst, during a black and white transmission, V_1 does not conduct; hence no burst reaches the phase detectors. Capacitor C_1 is a color shading (hue) control located at the front of the receiver. It determines whether the resonant circuit L_1C_1 is slightly inductive or slightly capacitive to the burst and thus, determines the precise phase relationship of the amplified burst with respect to the applied burst.

Phase Detector

Tuned to 3.58 mc, the secondary of T_3 in Figure 3A is tightly coupled to a primary located in the plate circuit of the burst amplifier. Opposite ends of the secondary connect to separate triode tubes. These tubes V_2 and V_3 are connected as grid-cathode diodes and the plates, tied to ground through the R_9C_{10} and R_8C_9 networks, act as shields.

In this detector, the phase of the incoming burst is compared with the signal fed from the oscillator through a color phasing amplifier to the phase detector.

The color reference bursts, coupled to the secondary of T_3 are applied to the grid-cathode diodes V_2 and V_3. Although the burst may consist of 8, 9 or 10 cycles, only one cycle is used in the following description. Since these diodes are connected in series across the T_3 secondary, conduction takes place only on one half of each cycle.

The conduction period is illustrated by the solid line curve, and the nonconduction time by the dashed line curve. Negative half cycles are applied through C_7 to the cathode of V_2 and positive half cycles through C_8 to the grid of V_3. The diodes conduct in series charging C_7 and C_8 to the polarity shown and in the direction of the arrows. R_{10} is at ground potential at this time.

During the charging interval, electrons flow from the negative end of the secondary T_3 to the negative plate of C_7. From the positive plate of C_7, the electrons flow through diodes V_2 and V_3, from cathode to grid, to the negative plate of C_8. Electrons flow from the positive plate of C_8 to lower positive end of the T_3 secondary. Conduction of the diodes charge the capacitors to peak voltage of the sine wave. Potentiometer R_{11}, which is called the apc balance control, balances the voltage applied to each half of the circuit. Proper adjustment is necessary to assure positive control by the circuit.

When the remaining half of the cycle (in dashed lines) is applied, the diodes do not conduct. During this time, capacitors C_7 and C_8 of Figure 3A discharge slightly through the T_3 secondary, R_7, R_{11}, and R_6. This action places a bias on diodes V_2 and V_3. Therefore, the phasing voltage applied to the detector from V_1 does not cause conduction during this interval.

The bias across each diode is made equal by adjusting the slider of R_{11} so that the resistance of the lower part of R_{11} plus R_7 equals the upper part of R_{11} and R_6. With the bias opposing the conduction of V_2 and V_3, only the peak of the burst with the polarity shown on the T_3 secondary can overcome this d-c voltage. Operating in this way, diodes V_2 and V_3 serve as an electronic switch.

A comparison voltage from the local 3.58 mc oscillator is amplified and applied to the phase detectors across R_{10}. The amplitude of this signal is not sufficient to overcome the bias provided by C_7 and C_8, and the phasing voltage is unable to cause conduction of the diodes. However, during the intervals the diodes are driven into conduction by the reference burst, small portions of the oscillator signal are impressed across the phase detectors.

When the oscillator voltage, applied to R_{10}, is going through zero at the instant the burst causes conduction of the diodes, no control voltage is developed. With a negative voltage applied to R_{10} at the instant the diodes V_2 and V_3 conduct, an added conduction takes place in V_3 with less in V_2 due to the oscillator signal. The electron flow is through V_3 from cathode to grid, through C_8 to the T_3 secondary center tap. From the center tap down through C_{19} and $R_{17}C_{20}$ to ground. and to the bottom end of R_{10}.

With a positive oscillator voltage applied to R_{10}, the conduction is increased through V_2 while it is now less through V_3. Electrons flow from ground up through C_{19} and $C_{20}R_{17}$ to the secondary center tap. From the center tap, the electrons flow through C_7, cathode to grid of V_2 to the top of R_{10}. The voltage developed across the low pass filter $C_{19}R_{17}C_{20}$ is the control voltage. It may be positive or negative depending upon the direction of charging current.

The phase relationships of the reference burst and oscillator wave-forms for the three conditions shown in Figure 4 illustrate the development of control voltage more completely. In Figure 4A, a negative pulse is applied to the V_2 cathode and a positive pulse to the grid of V_3 while the oscillator voltage is crossing its zero axis. It must be remembered that only the peaks of the burst voltage cause the diodes to conduct. Although the burst pulses cause V_2 and V_3 to conduct, the oscillator voltage is zero at these instants, therefore the charge on C_{19} remains at zero.

The color television receiver is designed to provide either color or monochrome pictures for home entertainment. The front panel controls are, from left to right, on-off-volume, chroma, horizontal and vertical hold, contrast, and station selector.

Courtesy General Electric Co.

A slight increase in the local 3.58 mc oscillator frequency results in the phase relationship shown in Figure 4B. Here, the oscillator voltage is small and positive most of the time, making V_2 grid more positive. This positive voltage across R_{10} causes V_2 to conduct more, charging capacitor C_{19} positive with respect to the ground end. This is a control voltage which is applied to the reactance tube to reduce the oscillator frequency.

This positive voltage aids the pulse applied to V_2 and subtracts from the pulse applied to V_3. Thus, V_2 conducts more than V_3. The additional current through V_2 is supplied by the charging current of C_{19}. Electrons flow from ground to the lower plate of C_{19} and from the upper plate to the T_3 secondary center tap. From the center tap, electrons flow through the upper winding to the negative plate of C_7. Other electrons flow from the positive plate through V_2, cathode to grid, to the top of R_{10}.

With a slight decrease in the oscillator frequency, the phase relationships are as shown in Figure 4C. The oscillator voltage at the top of R_{10} is mostly negative at the time the reference burst causes conduction of diodes V_2 and V_3. With a negative oscillator voltage applied, V_3 conducts more than V_2.

The additional electrons flow from the V_3 cathode to the grid and then to the negative plate of C_8. From the positive plate, other electrons flow through the lower winding of T_3 to the center tap and down to the upper plate of C_{19}. Other electrons flow from the lower C_{19} plate to ground and up through R_{10} to the V_3 cathode.

When the electron flow is in this direction, a negative control voltage is developed across the $C_{19}R_{17}C_{20}$ low-pass filter. Since, a negative control voltage applied to the reactance tube increases the 3.58 mc oscillator frequency, the oscillator phase is corrected automatically by this circuit.

In one narrow band chrominance receiver, diodes are used in place of triodes for phase detection. Figure 3B shows the circuit which is identical in operation to that of Figure 3A. The heavy arrow lines indicate the charge path of C_7 and C_8. Resistor R_{11} again is the balance control. Using the analysis of Figure 4, the 3.58 mc oscillator signal is impressed across L_1 and L_2, the output of the low pass filter $C_{10}R_{10}C_{11}$ is either zero or a + or − voltage. Again a negative control voltage changes the reactance tube to increase the oscillator frequency, while a positive voltage causes the reactance to decrease the oscillator frequency.

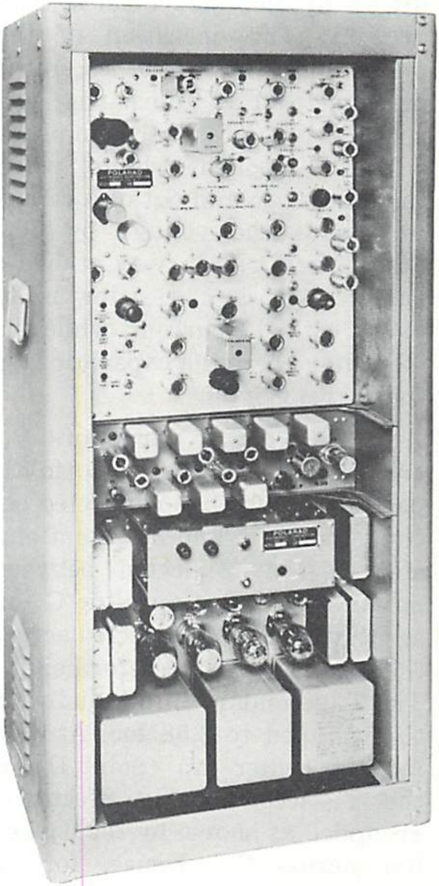
Phase Control Amplifier

In the apc system of a wide band chrominance receiver the

phase control amplifier V_4 shown in Figure 5A controls the oscillator phase. This amplifier stage determines the phase of the signal fed to the detectors for comparison. By adjusting this circuit the exact phase of the oscillator with respect to the reference burst can be controlled. Potentiometer R_{16} is located on the front panel of the receiver and is called the phase or **hue control.** The adjustments are made by the operator to correct the phase of the oscillator. When the sampling oscillator output is of the correct phase the proper colors are reproduced in the image.

The reference with which the local oscillator voltage is compared is the transmitted color burst. In the transmitter, the phase relationship of color sync signal and the chrominance subcarriers are determined with respect to the phase reference. For the color burst, the phase relationship is the phase reference plus 180°. The I and Q chrominance signals are in quadrature (90°), and the Q signal leads the phase reference by 33°.

In order for the correct colors to be reproduced in the receiver, the relative phase of the color burst and I and Q signals must be retained. However, the color burst is used as the reference in the receiver and to retain the same relative phase relationships, the I and Q signals must lag the burst. Thus, the phase control amplifier V_4 is provided to shift the phase of the oscillator output with respect to the color burst.



This color synchronizing generator furnishes NTSC color subcarrier frequency and driving, blanking and sync pulses. It is used to drive color bar generators and other NTSC color generating equipment.

Courtesy Polorad Electronics Corp.

To illustrate the phase shift network of the V_5 stage, it is redrawn in simplified form in Figure 6A. The operation of the phase shift circuit is based on the principle that an alternating current through a resistor is in phase with the applied voltage, while the current in and out of a capacitor leads the voltage by 90°. Stated in another way, the a-c voltage across a resistor is in phase with the current, while the a-c voltage across a capacitor lags the current by 90°.

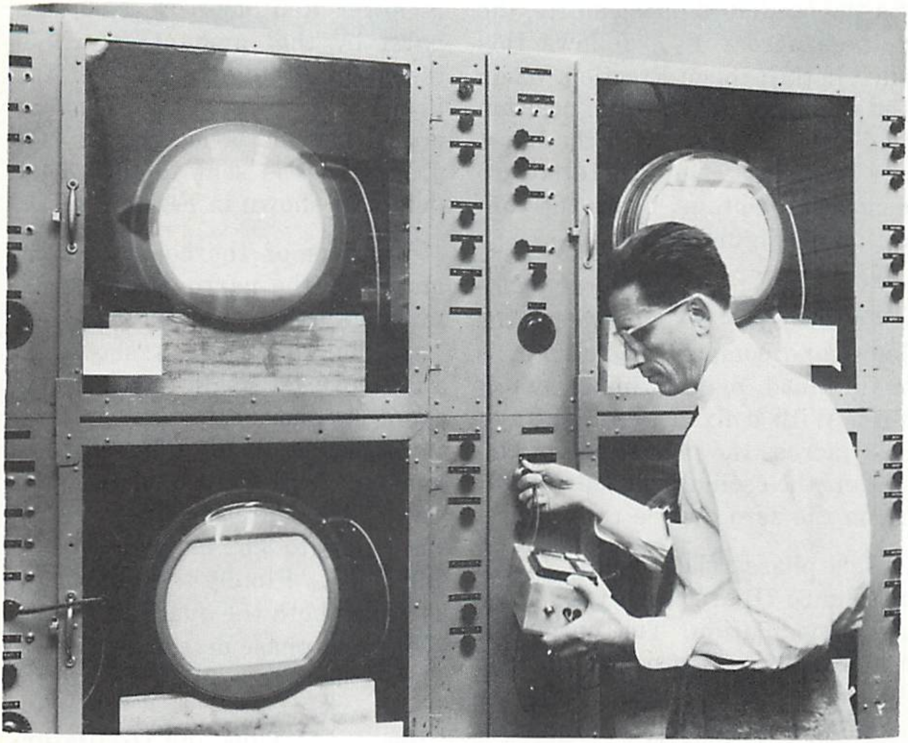
In Figure 6A, capacitors C_{11} and C_{12} are combined to form capacitor C_{eq} which is connected between points A and P. Potentiometer R_{16} is connected between points P and B. Capacitor C_{eq} in series with R_{16} is connected across the secondary of transformer T_4. The T_4 secondary in parallel with C_{13} is tuned to 3.58 mc. At 3.58 mc, the center tap (point O) of the T_4 secondary is effectively grounded as shown by the dashed line across C_{15}. Hence, for all practical purposes R_{10} is connected between points P and O.

Ideally, the phase relationship between the current and voltage is an RC network with a-c applied as shown with the aid of vectors.

Figure 6B is the equivalent circuit of Figure 6A. Taking E_{osc} as the phase reference voltage which it really is by the FCC Standards, it is drawn horizontal and to the right in Figure 6C. The total current in an RC circuit leads the applied voltage by some angle depending upon their values. Therefore, I_T is some positive angle from E_{osc}. Positive angles are measured in a counterclockwise direction while negative angles are measured in a clockwise direction. Since the voltage across a resistor is in phase with the current through it, $E_{R_{16}}$ is drawn larger than I_T at the same angle since it is $I_T R_{16}$. Now, the voltage across C_{eq} lags $E_{R_{16}}$ by 90°.

However, to complete the story of Figure 6A we must go one step further with Figure 6B. Figure 6D is a closed Figure drawn using $E_{C_{eq}}$, E_{osc}, and $E_{R_{16}}$ of Figure 6C. Note that the E_{osc} is still horizontal and $E_{C_{eq}}$ is drawn in the same position. Voltage vector $E_{R_{16}}$ is drawn in the same direction but from the arrow end of $C_{C_{eq}}$. This closed figure tells a familiar story: the voltages of the entire circuit must equal the applied voltage E_{osc}. Figures 6C and 6D really mean the same thing except that Figure 6D is more to the point. Corresponding points of Figure 6A appear on Figure 6D. Thus, the voltage across the primary between A and B is represented by the vector from A to B in Figure 6D. Voltage vector $E_{R_{10}}$ is then from O to P considering C_{15} in Figure 6A as a direct connection.

Whenever R_{16} is adjusted, voltage vectors $E_{R_{16}}$ and $E_{C_{eq}}$ change in direction (phase) and length



Color picture tubes are given a life test by producing an unmodulated raster on the screen. The raster is produced by deflection oscillators similar to those used in the TV receiver.

Courtesy General Electric Co.

(amplitude). As a result, voltage vector $E_{R_{10}}$ changes in direction but not in length since it swings around on the arc of a circle. This happens because E_{osc} is a constant voltage amplitude.

For proper operation of the phase detectors with zero correction voltage out, the burst must lag the comparison voltage $E_{R_{16}}$ by 90°. Figure 4A illustrates this condition very nicely. To V_2 and V_3 are applied 180° out of phase voltages. When $E_{R_{10}}$ is applied to each diode section as shown by the middle part ($E_{R_{10}}$) of Figure 4A, the output voltage is zero. This is shown in Figure 6D in vector form by the broken arrow at P′.

In Figure 7A, when $E_{R_{10}}$ is less than 90° from the burst, also indicated by Figure 4B, the oscillator voltage is some angle L away from the voltage vector $E_{R_{10}}$.

A d-c correction voltage is fed to the reactance tube which changes the oscillator frequency.

As the oscillator phase shifts, the voltage across $E_{R_{10}}$ follows this shift in the proper direction. When the oscillator reaches the position in Figure 7B, $E_{R_{10}}$ and the burst are 90° apart. Now there is zero correction voltage, being the condition of Figure 4A.

Working backwards, a phase difference of 90° between the burst and comparison voltages is maintained by the phase detectors. With a fixed phase shift of 123° across the phase control amplifier, the oscillator is shifted 33° from the zero degree reference.

The phase relationships shown in Figure 7B are correct for proper demodulation. The output of the oscillator may be fed directly to the Q demodulator, while the same voltage is fed to a quadrature amplifier for the I demodulator. Any shift of the relative phase relationships causes improper hue of the colors in the reproduced image.

In one type of narrow band chrominance receiver, there is no phase control amplifier. The hue control is part of the parallel resonant circuit in the burst amplifier of Figure 2B and is C_1, referred to as the color shading control. Here the resonant tank is adjusted until it is in phase with the burst signal which then develops a maximum voltage across the tank. If it is not tuned exactly to 3.58 mc, the voltage developed is lower and lags or leads the burst by that amount. Thus, in the plate circuit C_4, R_4, and the primary of T_3, being resonant about 3.58 mc, a leading or lagging signal is sent to the phase detectors shown in Figure 3B.

In place of the color phasing amplifier, the narrow band chrominance receiver uses an ordinary buffer stage as shown in Figure 5B to isolate the oscillator from the phase detectors. To keep its input circuit impedance rather constant, fixed cathode bias is used. The plate circuit is tuned very close to 3.58 mc by the peaking coil L_6. Finally the subcarrier is fed to both the quadrature network and phase detector which is shown in Figure 3B.

Reactance Tube and Oscillator

In the color television receiver, a 3.58 mc subcarrier is generated and used to demodulate the chrominance signal. The local subcarrier must be of the same frequency and phase as the subcarrier used for modulation in the transmitter. Usually, a crystal controlled oscillator is used to provide a stable frequency and a reactance tube to control its phase.

A reactance tube and 3.58 mc crystal oscillator circuit is shown in Figure 8A. The oscillator V_6 is operated as a cathode follower. When operated in this manner, a signal fed back from the oscillator is reduced. Otherwise these would cause spurious oscillations in the reactance tube plate tank L_2C_{24} which would change the phase of the oscillator output voltage.

Transformer T_5 is tuned to a frequency which is slightly lower than the crystal frequency. Hence, the T_5 primary presents a capacitive reactance to the 3.58 mc frequency which is necessary to maintain oscillations. The feedback voltage is coupled to the grid by capacitor C_{28} and the grid-cathode capacitance of the tube. The crystal determines the phase and frequency of the subcarrier coupled by the T_5 secondary and capacitors C_{29} and C_{31} to the demodulator circuits. C_{29} and C_{30} form a capacitive voltage divider which reduces the signal amplitude fed to the phase control and quadrature amplifiers.

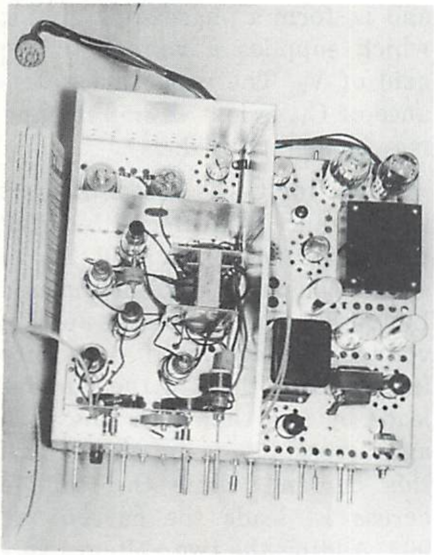
The reactance tube V_5, connected in parallel with the crystal, functions as a variable capacitance. It is biased by a voltage divider R_{19}, R_{20}, R_{21}, and R_{22} and, also, by self bias provided by the plate current to the center of the I_b-E_c characteristic curve. Hence, the reactance can be changed by any voltage applied to the grid. The capacitive reactance is decreased by a positive grid voltage and increased by a negative voltage.

In Figure 8A, an a-c voltage from the crystal is coupled by capacitor C_{26} to the plate of V_5. The normal d-c plate voltage is applied through R_{22} and coil L_2. Also, connected across the crystal, C_{22}, R_{18}, and L_1 form a phase shift circuit which supplies a voltage to the grid of V_5. The capacitive reactance of C_{19} is low at 3.58 mc and may be disregarded.

Capacitor C_{22} is chosen so that its reactance is much greater than the impedance of L_1 and R_{18} in series, causing a current through L_1 and R_{18} which leads the applied voltage. However, with resistance in series with C_{22}, the current leads by less than 90°. The voltage across R_{18} is in phase with this current, while the voltage across L_1 leads the current by 90°. Adding the two voltages vectorially $E_{R_{18}}$ and E_{L_1} results in a voltage applied to the grid of V_5 which leads the applied voltage by approximately 90°.

In phase with the grid voltage, the current leads the plate voltage by 90°. With the current leading the applied plate voltage, the reactance tube has the same effect as a capacitor connected in parallel with the crystal. An increase in plate current corresponds to an increase in capacitance and a decrease in current corresponds to a decrease in capacitance.

To illustrate the operation of the reactance tube circuit, assume a shift in phase occurs which corresponds to an increase in oscillator frequency. Referring to Figure 4B, this phase of oscillator signal compared to the color sync burst in the phase detector results in a positive d-c correction voltage applied across C_{19} in Figure 8. Under these conditions, a positive voltage is applied to the grid of V_5 causing an increase in plate current.



Top view of the deflection and high voltage chassis used in the color receiver. As in the monochrome receiver, the high voltage components are enclosed in a metal cage.

Courtesy Sentinel Radio Corp.

The increase in the reactance tube plate current is equivalent to increasing the capacitance represented by the tube. By this action, the larger capacitance placed in parallel with the crystal decreases the oscillator frequency until the phase relations in the detector return to the normal condition as shown by Figure 4A and no further correction voltage is applied to the grid of the reactance tube.

Conversely, with a decrease in the oscillator frequency and phase, the phase relationship of the burst and oscillator output are as shown in Figure 4C. In this case, the d-c correction voltage applied to the reactance tube grid by the phase detectors is negative. A negative voltage on the grid of V_5, Figure 8A, decreases the plate current. This is the equivalent of a smaller capacitor in parallel with the crystal and the frequency increases. Again, when the proper phase and frequency is reached, the correction voltage is reduced to zero.

Figure 8B is a slightly different reactance tube oscillator used in a narrow band chrominance receiver. The main difference between the two is that stage V_6 has a grounded cathode and has a tuned-plate circuit instead of a cathode follower type output. Again the coil is tapped down to get an impedance match so that the 3.58 mc is not disturbed in phase going to the buffer amplifier. Since the buffer amplifier merely isolates the oscillator section from the phase detectors, a cathode follower output is not required.

COLOR KILLER

The phase detector of Figure 3A is redrawn in Figure 9 with the **color killer** circuit added. The purpose of this circuit is to prevent picture signals from passing through the chroma channels in the receiver during monochrome reception. During monochrome reception the color killer tube conducts developing a negative voltage in its output. This voltage is used as a cutoff bias in the chroma channel.

When a color signal is received, the color killer tube V_7 must be cut off to allow the chroma channels to operate. The color burst included in this signal is applied to the phase detectors, V_2 and V_3. These conduct, charging C_7 and C_8 to the polarities shown in Figure 9. Capacitor C_8 charges to a peak of the 60 volts applied to the grid of V_3.

The voltage divider in the V_7 grid circuit is connected to the junction of C_8 and R_7 thus providing an additional discharge path for C_8. Following the electron path, they flow from the negative plate of C_8 through resistors R_{27} and R_{28}, then through the B supply to ground. From ground electrons flow to the lower plate of C_{19}. Other electrons flow from the upper plate of C_{19} to the center tap of T_3 and down through the lower half of the winding to the positive plate of C_8.

Although the direction of electron flow is in a direction which develops a positive control voltage across C_{19}, it has little effect on the oscillator because of the small current. Also, notice that the voltage across C_8 is in series with the B+ supply. However, the bias is determined by the difference in the drop across R_{28} and B+.

To illustrate the bias applied to V_7 under these conditions, the following values are assumed:

$R_{28}=100$ meg $R_{27}=5$ meg $B+300V$

The total resistance of the series voltage divider is:

$$R_T=R_{28}+R_{27}$$

$$R_T=100{,}000{,}000+5{,}000{,}000$$

$$R_T=105 \text{ meg}$$

However, the voltage applied to the voltage divider is B+ plus the capacitor C_8 voltage. Thus, the current in the divider is:

$$I=\frac{E_B+E_{C_8}}{R_T}$$

$$I=\frac{300+60}{105{,}000{,}000}=\frac{360}{105{,}000{,}000}$$

$I=.00000343$ Amp. or $3.43\ \mu$Amps.

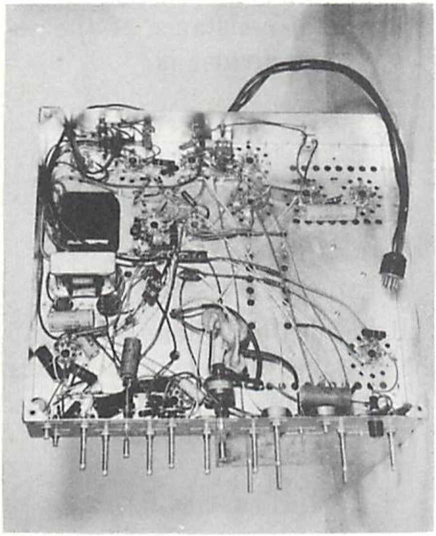
The voltage across R_{28} is:

$E_{R_{28}} = I \times R_{28}$

$E_{R_{28}} = .00000343 \times 100{,}000{,}000$

$E_{R_{28}} = 343V.$

The voltage across R_{28} is negative at the grid end, therefore, the difference between $E_{R_{28}}$ and B+ is a negative voltage at the grid. That is, the difference in a −343V and 300V is −43V. This voltage is sufficient to cut off V_7. Although a positive pulse is applied to the plate of V_7, no conduction takes place and the output is zero.



Bottom view of the deflection chassis shown in the preceding illustration. Note the heavy insulation used on the high voltage components.
Courtesy Sentinel Radio Corp.

When a monochrome signal is transmitted, the color burst is omitted, and the charges across capacitors C_7 and C_8, in the phase detector, reduce to zero. Under these conditions, all of the components in the phase detector circuit no longer have any effect upon the voltage applied to the grid of V_7. The entire B+ voltage of 300 volts is now divided between the 100 megohms of R_{28} and the internal grid resistance placed effectively between the grid and cathode of V_7 due to the fact that there is an electron flow from the cathode to the grid.

The resistance that is offered by the grid-cathode circuit is very low—approximately 1000 ohms—so that practically all of the B+ voltage is dropped across R_{28}, leaving the grid of V_7 just a fraction of a volt positive in respect to the cathode. With the bias removed, the color killer tube (V_7) conducts quite heavily.

Transformer T_6, in the plate circuit of V_7, is a secondary on the horizontal output transformer. During horizontal flyback time a positive pulse is applied to the plate of V_7 causing it to conduct. The plate current of V_7 charges C_{33} to the polarity shown. Between pulses C_{33} discharges slightly through R_{29} providing a d-c voltage. This voltage is applied to the grid of the input chroma amplifier which biases it to cutoff. Therefore, monochrome signals are blocked in the chroma channels.

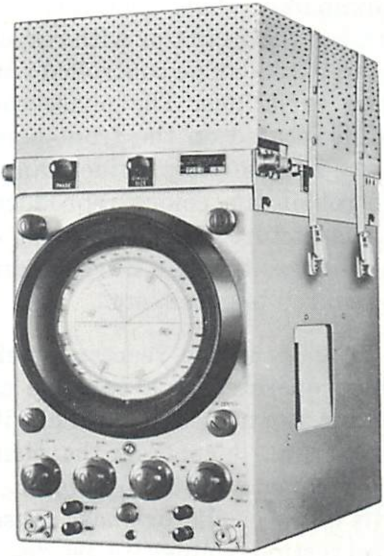
In some color TV receivers, conduction of the color killer tube is not actuated by a horizontal pulse applied to the plate. However, the bias in the color killer is practically always obtained from the rectified burst signal so that the overall operation of the circuit remains the same.

TWO COMPLETE APC CIRCUITS

A circuit diagram of the discriminator type apc circuit used in some wide band chrominance receivers is shown in Figure 10A. Tube V_1 is a gate burst amplifier. The burst is transformer coupled from the video amplifier to the grid of V_1 by T_1. Biased to cutoff, V_1 conducts only when a gating pulse is applied to the cathode by T_2 located in the horizontal deflection circuit.

When the gating pulse and color burst appear at the cathode and grid of V_1, respectively, at the same instant, the burst is amplified and appears in the plate circuit. Transformer T_3 couples the burst to the phase detectors V_2 and V_3. The apc balance control R_{11} is adjusted to allow equal conduction of V_2 and V_3 when the burst is applied. Misadjustment of R_{11} permits the oscillator to operate at the wrong phase. Also, a comparison voltage is applied to the detectors from V_4. The output of the phase detector is a d-c voltage used to control the phase of the sample oscillator.

At the junction of R_7 and C_8 is a negative d-c output which is applied to the grid of the color killer tube V_7 through R_{27}. This voltage is sufficient to overcome the positive voltage from the B+ divider to cut-off the tube during color reception. Otherwise, during black and white reception, the tube conducts charging C_{33} to the polarity shown, keeping the bandpass amplifier cut-off.



A modified oscilloscope, called a vectorimeter, shows the phase relations of the I and Q signals with respect to the burst in vectors on the CRT screen. The color decoder, burst-controlled oscillator, and power supply are contained in the chassis fastened on top of the "scope".

Courtesy Wickes Engineering and Construction Co.

The phase control amplifier V_4 has the output of the oscillator applied to the grid. By adjusting the phase control R_{16}, this amplifier maintains a fixed phase relationship between the oscillator and the comparison voltage. The phase range provided by V_4 is approximately 150°, therefore, the phase of the oscillator with respect to the burst can be controlled with large variations. The phase control is located on the front panel of the receiver to provide manual control of the colors reproduced in the picture. Misadjustment of R_{11} changes the hue. Blue changes to red, red to green, etc.

Tube V_5 is the reactance tube which operates as a variable capacitor. Connected in parallel with the crystal, it controls the phase and frequency of the oscillator. A shift in the oscillator phase causes a correction voltage to be developed by the phase detectors. Applied to the reactance tube, this voltage changes the capacitance in that direction which corrects the phase of the oscillator frequency.

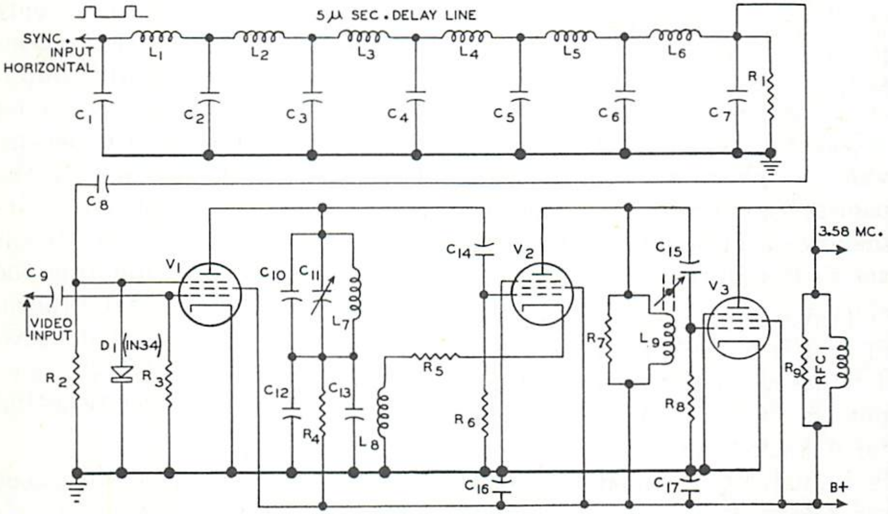
The oscillator V_6 is crystal controlled and is operated as a cathode follower to prevent spurious oscillations from being generated in the reactance tube plate tank L_2C_{24}. The output of the controlled oscillator is applied to the demodulator circuits. The Q demodulator subcarrier is applied directly from the oscillator, while the oscillator output is carried through a quadrature amplifier to obtain 90° relation between demodulator signals.

This type of apc circuit has a fast recovery time and its phase control range is well within the ±5 degrees required to prevent noticeable color distortion. Other types of color synchronization circuits are used. However, the basic principles of operation are quite similar.

Figure 10B is the unified schematic of the circuits used in one type of narrow band chrominance receiver described in Figures 2B, 3B, 5B, and 8B. To avoid any confusion, being a narrow band chrominance receiver does not determine the type of color sync circuits used. The fact that these circuits are currently in use in such receivers is our way of making the distinction between the two main variations of discriminator apc circuits.

Tube V_1 is a gate burst amplifier which also phases the hues properly with the color shading control C_1. The burst is transformer coupled through T_1 from the video amplifier. Normally cutoff, V_1 conducts when a properly delayed horizontal sync pulse applied to the screen grid drives the tube into conduction.

Transformer T_3 tuned to 3.58 mc couples this signal to the phase detectors which compare it with the 3.58 mc oscillator voltage fed to V_2 and V_3 through buffer stage V_4. Balance control R_{11} adjusts V_2 and V_3 for equal conduction without a burst signal. When the burst is out of phase by some angle with the 3.58 mc applied at the plate of V_2 and cathode of V_3, a positive or negative d-c voltage is developed across the low pass filter network C_{10} R_{10} C_{11}. Whatever the d-c present on the grid of V_5, it shifts its reactance in the proper direction to bring the 3.58 mc to proper phase. The tuned-plate tuned-grid oscillator V_6 is sent through a buffer which feeds the quadrature network. In it, two 3.58 mc subcarriers appear as outputs exactly 90° apart. These are then applied to the R-Y and B-Y demodulator grids.



A variation of the ringing circuit. The 3.579545 mc signal is developed across a high Q circuit ($C_{10}C_{11}L_7$) instead of a crystal.

Note the absence of the color killer and 33° phase shift. Since the receiver is a narrow band, no 33° phase shift is necessary at the hue control in the burst amplifier. Also, a color killer is not used as the narrow bandwidth will reduce the possibilities of interference.

Normal operation of a balanced demodulator cancels out any of the 3.58 mc oscillator signal from V_6. Thus, no information passes through the color sync circuits or beyond the demodulators during a black and white reception.

CRYSTAL RINGING CIRCUIT

Figure 11 is the color synchronization circuit shown in the block diagram of Figure 1B. The circuit consists of a burst amplifier, a crystal ringing circuit, a phase shift amplifier, a limiter cathode follower, color killer doubler, and color killer. A constant amplitude 3.58 mc subcarrier of the proper phase is applied to the demodulators from this circuit.

As in the phase discriminator circuit, a gated amplifier is used to allow only the burst to be applied to the crystal ringing circuit. The gated amplifier V_1 receives the color burst from the video amplifier by means of the tuned transformer T_1. The secondary of T_1 is shunted by resistor R_1 to reduce phase shift.

Transformer T_2, the secondary of which is shown separately, is a winding on the horizontal output transformer. During horizontal flyback time a negative pulse is inductively coupled to the T_2 secondary. This pulse is applied to the cathode of V_1 to cause conduction at the instant the burst is present at the grid. The amplified burst is present across the plate tank circuit C_4 and the primary of T_3. Resistor R_4 is provided to reduce any phase shift in the 9 cycle burst by the tuned circuit.

The output of the burst amplifier V_1 is coupled to the crystal by transformer T_3. The crystal is operated as a series resonant circuit and an adjustable trimmer capacitor is provided to vary the resonant frequency. This provides a relatively wide range of adjustments so that the accuracy requirements of the crystal are less. In general, proper tuning results in a maximum output with minimum phase shift.

A train of oscillations is produced by ringing the crystal with a color burst. Since the burst is applied to the ringing circuit only during the horizontal blanking interval, some decay in the amplitude occurs during each scanning line. The amount of decay accompanied by phase shift during the line interval is related to the circuit Q. Generally, higher circuit Q is obtained by terminating the crystal with low resistances. Therefore, the secondary of transformer T_3 and resistor R_6 have relatively low resistance resulting in a more uniform output.

Although some phase shift does take place during the intervals between the color bursts, it is slight and it is corrected at the beginning of each scanning line. Therefore, the shift is not noticeable in the picture. The crystal is tuned so that the voltage across it is in phase with the burst.

The output of the crystal is applied to the cathode of a grounded grid amplifier V_2. Operated in this manner, when the plate circuit is tuned to resonance at the burst frequency, no phase inversion occurs in the signal between the cathode and plate. That is, when the voltage applied to the cathode is going positive, the signal at the plate is going positive, also. However, when the resonant circuit L_1C_8 is tuned to a frequency above or below 3.58 mc, the voltage at the plate shifts in phase with respect to the input signal.

Capacitors C_6 and C_7 prevent d-c from being applied to C_8 which is a front panel control. Also, C_8 is grounded on one end to prevent the r-f voltage from affecting the operator. C_8 is the hue control which is adjusted by the viewer for the desired reproduction of colors in the receiver image.

The phase of the subcarrier oscillator voltage in the transmitter is used as the reference from which the phase of the modulated subcarriers and the color burst is measured. The reproduction of the subcarrier in the receiver by the crystal ringing circuit is illustrated by the vector diagrams of Figure 12. As shown in the two Figures, the burst appears 180° out of phase with the reference subcarrier.

The voltage developed by the crystal in Figure 11 is in phase with the burst and, with respect to the reference (0 degrees), may be illustrated by the burst vector in Figure 12A, also. With the L_1C_8 tank tuned to 3.58 mc, the voltage at the plate of V_2 is in phase with the burst. The output of V_2 is applied to the grid of V_3 and its output is shifted in phase by 180°. Under these conditions, the output of V_3 is in phase with the reference, 0 degrees.

When the subcarrier is reinserted in the Q demodulator in phase with the reference, incorrect hues are reproduced. Also, in quadrature with the Q subcarrier, the I demodulator reproduces the wrong hue of colors. In the transmitter, the phase relationship of the subcarriers and the reference are as shown in Figure 12B. These same relationships must be retained in the receiver.

To accomplish this, the hue control, capacitor C_8, in the plate circuit of V_2 Figure 11, is varied until the output leads the input by 33°. This is illustrated by the dashed line vector located at 213° in Figure 12A. Applied to the grid of V_3, the phase is shifted 180° in the plate circuit, as shown in Figure 12B by the Q subcarrier vector.

The amplifier V_3, in addition to providing the necessary phase inversion of the sampling voltage, also serves as a limiter. When a burst is applied to the crystal ringing circuit a damped train of oscillations are produced. The build up and decay of the wave train during each interval provides a varying amplitude subcarrier. Other factors which cause variations are varying signal strength and noise impulses.

When large variation occurs in the sampling frequency, improper demodulation results which degrades the reproduced colors. To prevent this type of color distortion, tube V_3 is operated as a limiter. The output amplitude of V_3 is a fairly constant subcarrier of 3.58 mc regardless of normal input variations.

The output of V_3 is applied to a 3.58 mc cathode follower V_4. The 3.58 mc subcarrier for the Q demodulator is taken off at the junction of R_{14} and R_{15}. Variable inductor L_3 and C_{14} provide a 90° phase shift for the 3.58 mc subcarrier. Capacitor C_{15} is just a large coupling capacitor. Therefore, the I subcarrier is taken at the output of this cathode follower.

Also from the output of V_3 is a 3.58 mc pulse to a voltage doubler, labelled color killer doubler. A high voltage pulse is required to keep V_7 cut off so there is no voltage available at C_{22} to cut off the demodulators. Capacitors C_{17} and C_{19} make up the voltage doubling circuit. Along with C_{19} and R_{19}, C_{18} forms a pi filter. Thus, a high negative direct voltage is available to the impedance load $R_{20}C_{20}$. During color telecasts the 3.58 mc signal causes V_6 to conduct and apply a negative voltage to the grid of V_7. The positive horizontal pulses at the plate of V_7 do not cause conduction, thus no voltage is developed across C_{22}. However, when no 3.58 mc burst is present, no voltage is developed at the grid of V_7. A high horizontal gating pulse off the flyback transformer drives V_7 into conduction. Electrons flow through its plate through R_{21} and C_{22} to ground. Thus, the electrolytic C_{22} applies a high negative d-c voltage to the demodulator grids holding them cut-off. Therefore, no luminance information can pass through the color sync or color demodulation sections.

DEFLECTION SYSTEM

A color television receiver has two synchronization channels: (1) the color sync circuits and (2) the deflection sync circuits. The synchronization system used to control the beam deflection in the tri-color picture tube is the same employed in present day monochrome receivers.

The sweep sync voltages employed for color and monochrome transmission have the same wave shape and frequency. Although for monochrome, the vertical and horizontal sync frequencies may be 60 and 15750 cycles, for color the vertical sync must be 59.94 cps and the horizontal sync frequency is 15734 cps.

To assure compatibility of the present monochrome and color systems, synchronization must be maintained by the sync pulses contained in either signal for both type receivers. That is, the monochrome receiver deflection circuits must operate at the vertical frequency of 59.94 cps and a horizontal frequency of 15734 cps when receiving a color signal without circuit changes or manual adjustments. Conversely, the color receiver deflection circuits must operate at the monochrome sync frequencies when receiving a monochrome signal.

The sweep synchronization circuits in both the color and monochrome receivers operate equally well when receiving either type of signal. Since these circuits have been described in earlier lessons, they are not repeated here. However, a brief review of the overall deflection system, used in the color receiver, is given and illustrated by the block diagram of Figure 13.

The composite video signal, as indicated in the Figure, is applied to the block labeled sync clipper. This tube is biased well below cutoff by either a grid leak action or a fixed voltage. Therefore, only the positive peaks of the video signal, which consist of the sync pulses, cause conduction of the tube. The output of the sync clipper contains both the horizontal and vertical sync pulses.

In the following stage the vertical and horizontal sync pulses are separated and fed to their respective circuits. The integrated vertical sync pulse shown at the sync separator output is fed to the vertical oscillator. This waveform triggers the oscillator at the end of each field causing a new cycle to start. The frequency of vertical oscillator is 60 cps for monochrome signals, and 59.94 cps for color signals.

The vertical oscillator output voltage is a trapezoidal waveform which is required for magnetic deflection. It is increased in amplitude by the vertical output amplifier and coupled to the vertical deflection coils. In the color television receiver, a second waveform is obtained from the cathode of the vertical output tube and applied to a CONVERGENCE AMPLIFIER. The purpose of this parabolic wave-form is to control the three electron beams in the tricolor picture tube.

The second output of the sync separator consists of the horizontal sync pulses. These pulses are fed to an automatic frequency control (afc) circuit. Also, the output of the horizontal oscillator is fed back to this stage. The afc circuit compares the frequency of the oscillator to that of the sync pulses. When a frequency difference occurs, a d-c voltage is developed at the output proportional in magnitude and polarity to the frequency change.

Applied to the horizontal oscillator, this d-c voltage controls its frequency. The output of the horizontal oscillator is a trapezoidal wave-form at the horizontal sweep frequency. This wave-form is increased in amplitude by the horizontal output amplifier and applied to the deflection coils.

Although not shown in the block diagram of Figure 13, a flyback transformer is used to provide a high voltage for the picture tube. Also, a parabolic wave-form is obtained from the cathode of the output amplifier for beam convergence purposes in the tri-color tube. Both parabolic waveforms are often combined in the same convergence amplifier.

The timing of the horizontal output voltage relative to the incoming sync pulses is controlled by the afc circuit. Since this timing directly affects the relative position of the received color burst during the horizontal flyback period, stable operation of the afc circuit is particularly important.

None of the blocks of Figure 13 are circuits different from those found in black and white TV receivers. These were covered earlier in this training series. However, the convergence amplifiers are new circuits found in color TV receivers and they are described in detail in the following lesson. In fact, since the horizontal output amplifier plays such an important role in supplying gating pulses, it is also covered in further detail. The emphasis lies really on the voltages necessary for the picture tube.

* * *

IMPORTANT DEFINITIONS

AUTOMATIC PHASE CONTROL—(apc)—A circuit designed to maintain automatically the phase of an oscillator by comparing the phase of color burst to that of the oscillator output.

COLOR BURST—A synchronizing signal, consisting of approximately 9 cycles of the 3.579545 mc subcarrier frequency, which is transmitted to control the phase of the local subcarrier oscillator.

COLOR KILLER—A circuit designed to permit operation of the chroma channels of a color television receiver only during reception of a color picture.

CRYSTAL RINGING CIRCUIT—A method of color synchronization in which a train of oscillation is produced by ringing a high Q circuit with the color burst.

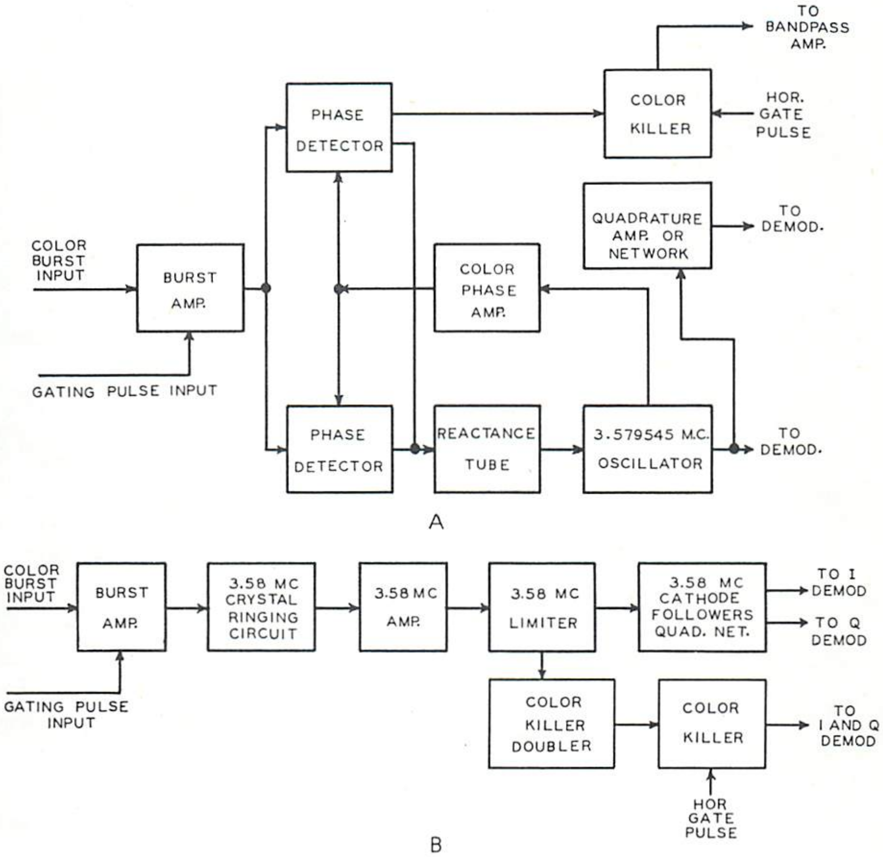
GATED BURST AMPLIFIER—An amplifier which is forced into conduction by a gating pulse during horizontal blanking time to separate the color burst from the composite video signal.

GATING PULSE—A pulse used to start, or stop, the conduction of a tube during certain timed intervals.

HUE CONTROL—In the color television receiver, a control by which the shade or hue of a color in the image may be changed.

PHASE CONTROL AMPLIFIER—In the color television receiver, a stage in which the phase of the output voltage may be varied with respect to the input.

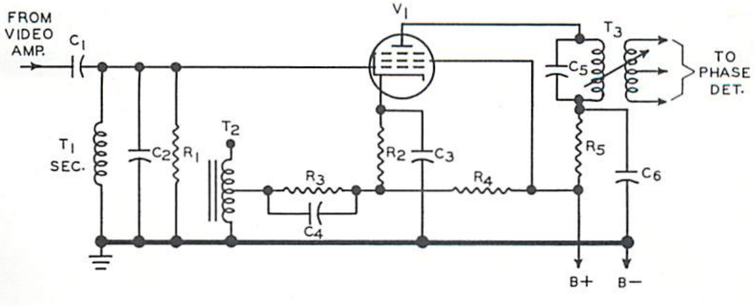
PHASE SHIFT CONTROL—See hue control.



A

B

FIGURE 1



A

FIGURE 2

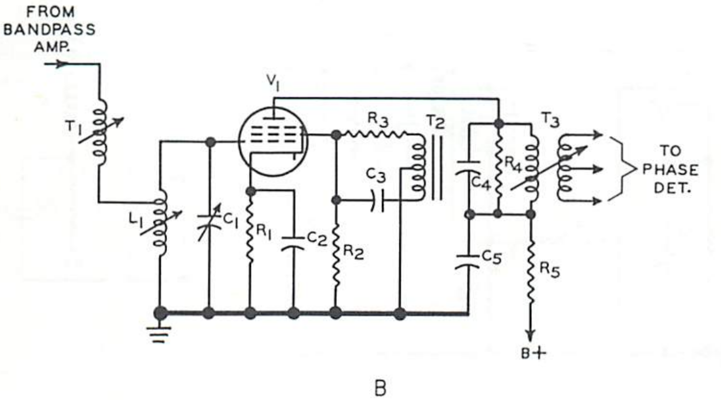


FIGURE 2

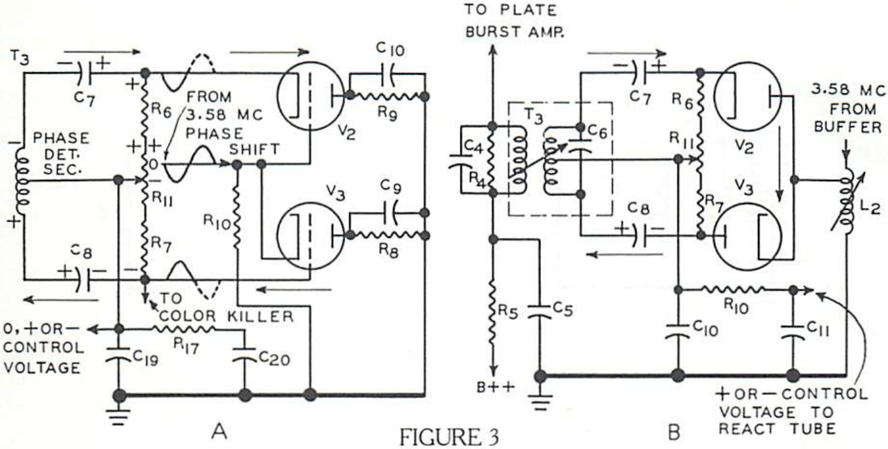


FIGURE 3

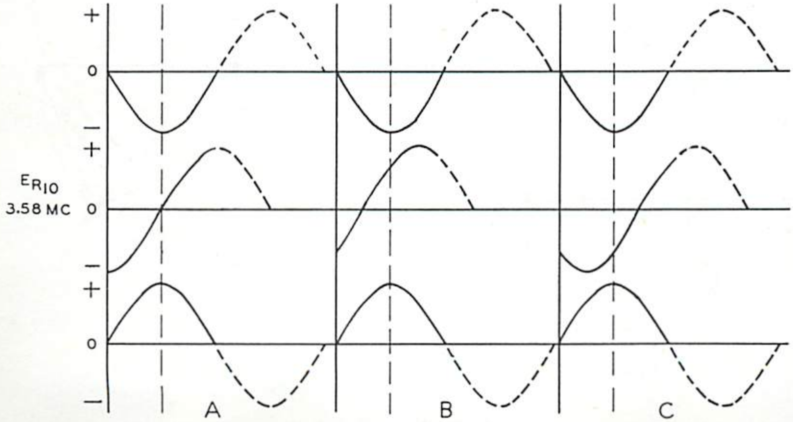
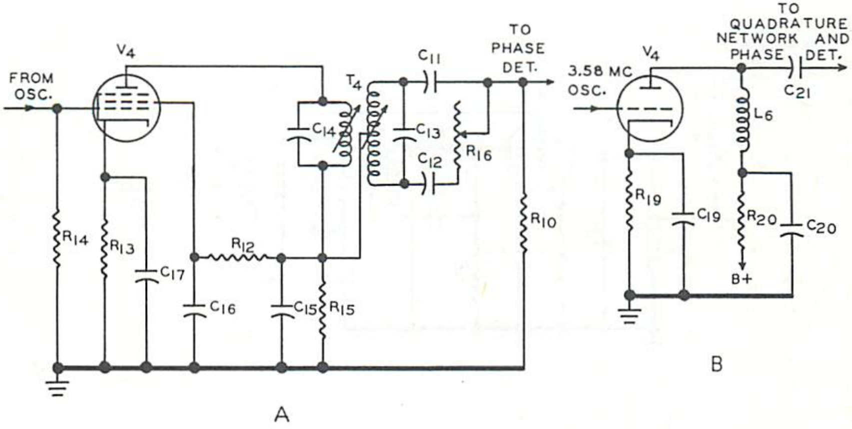


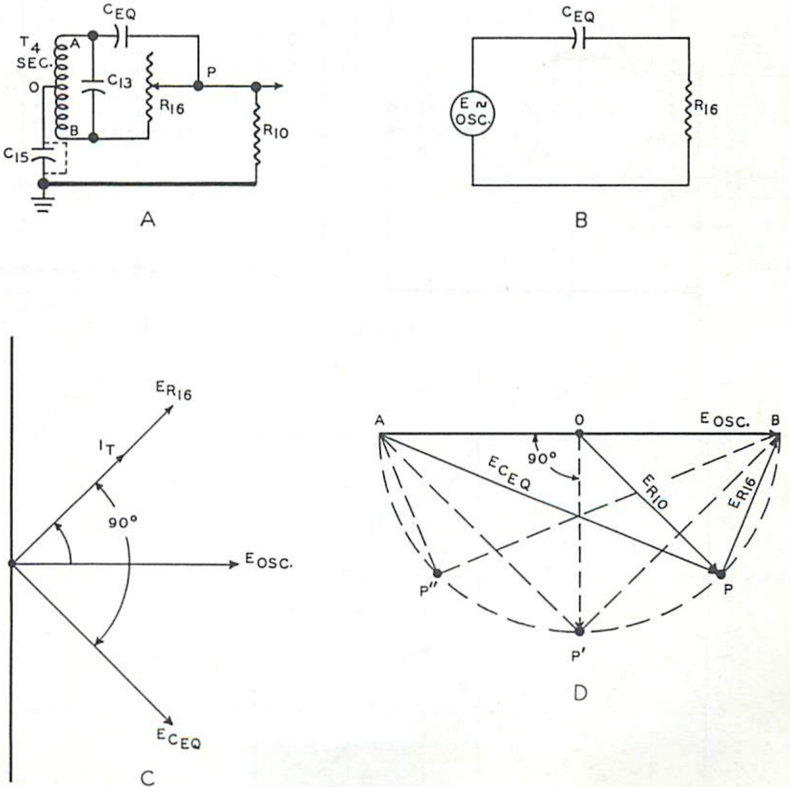
FIGURE 4



A

B

FIGURE 5



A

B

C

D

T4 E–10

FIGURE 6

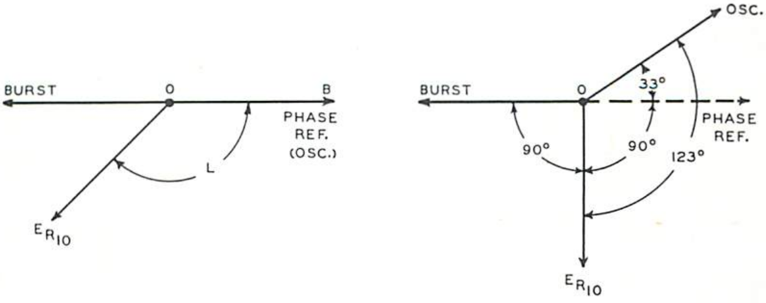


FIGURE 7

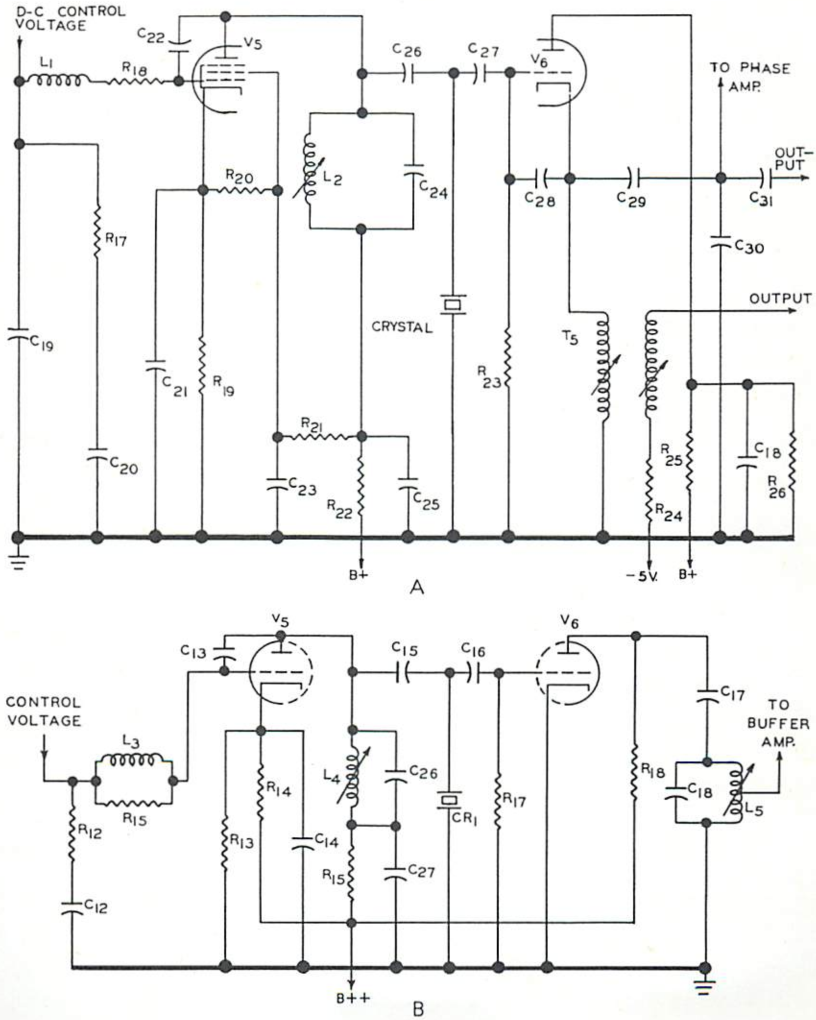


FIGURE 8

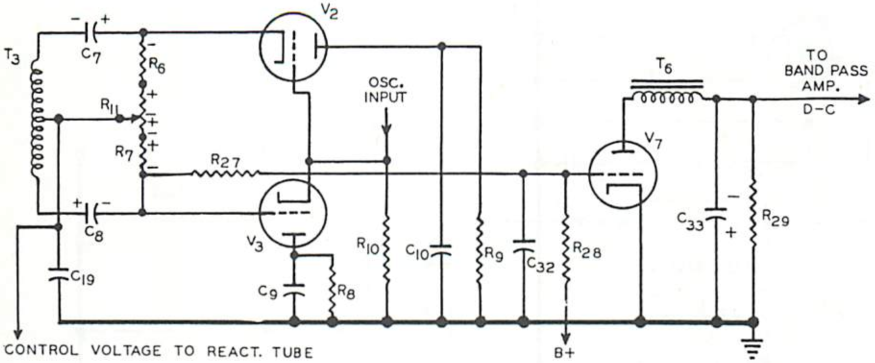


FIGURE 9

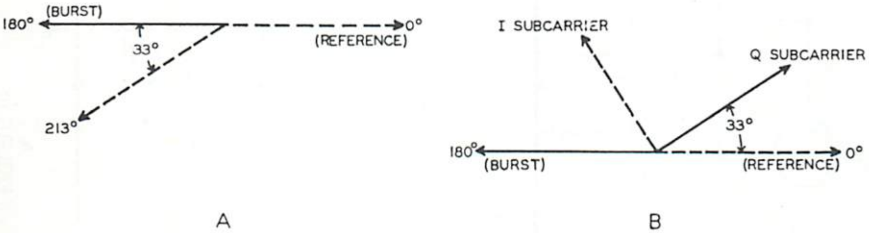


FIGURE 12

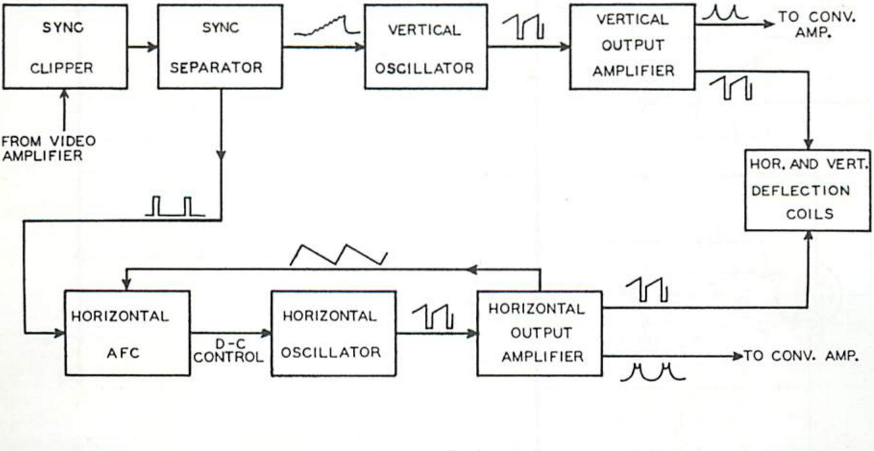
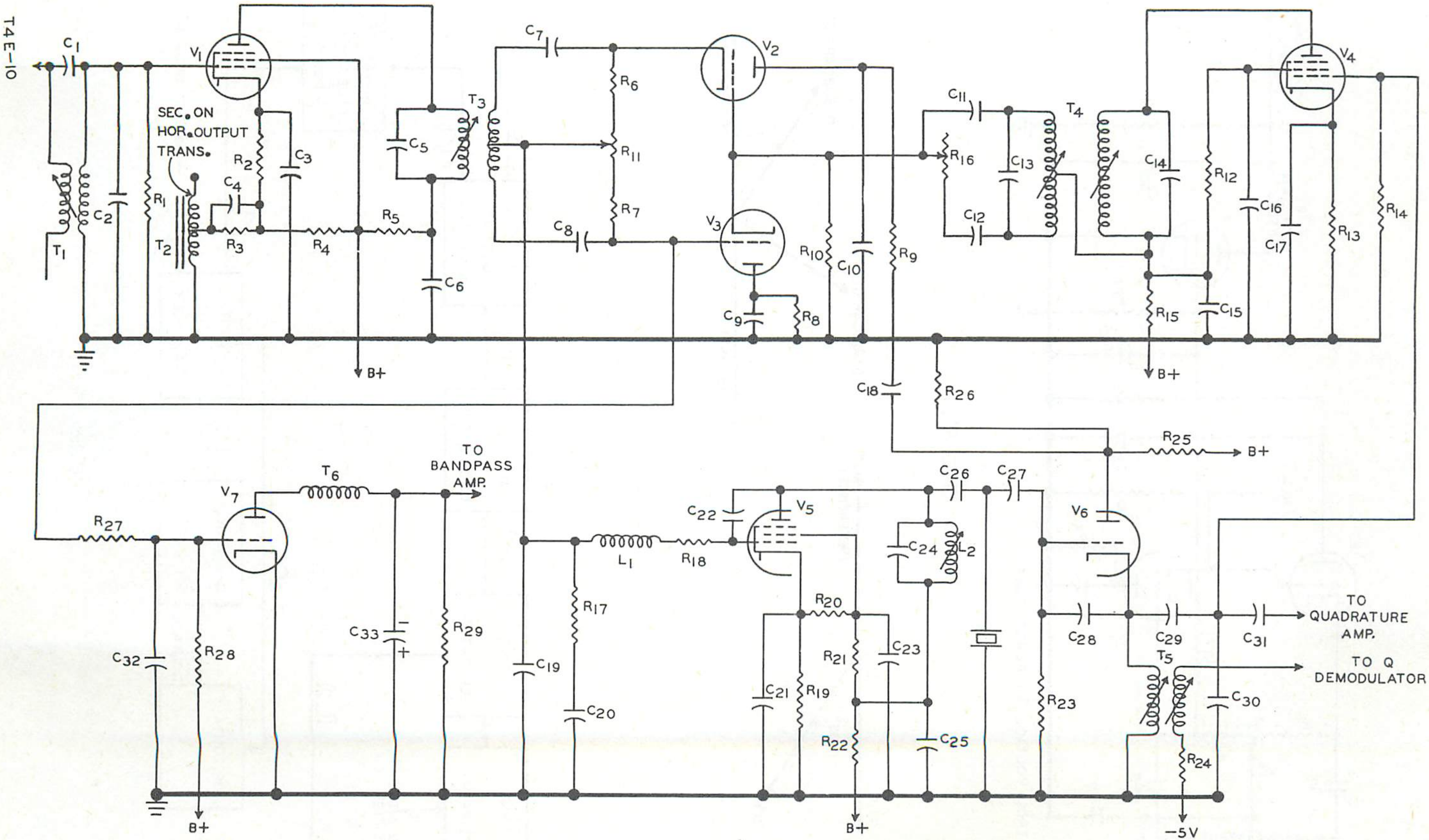
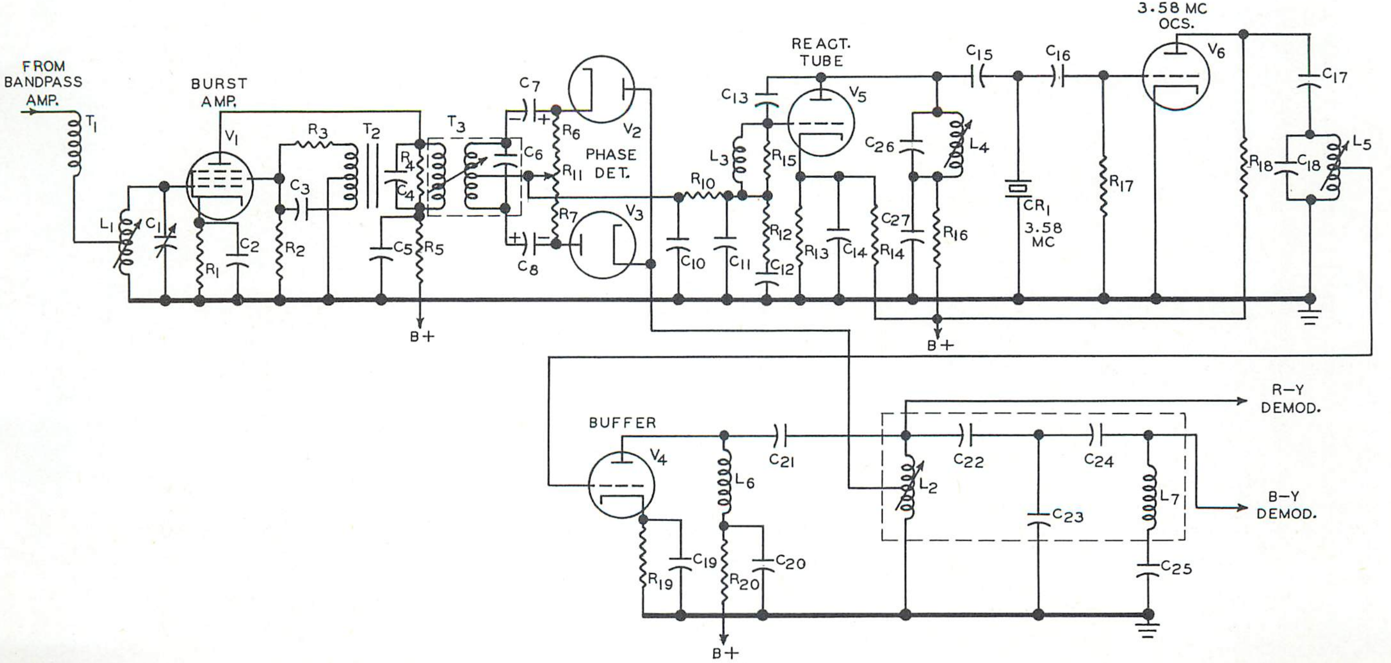


FIGURE 13


T4E-10
C1
V1
SEC. ON
HOR. OUTPUT
TRANS.
T1
C2
R1
T2
R2
C3
C4
R3
R4
R5
B+
C5
T3
C6
C7
R6
R11
R7
C8
V2
V3
C9
R8
R10
C10
R9
C11
R16
C12
C13
T4
C14
V4
R12
C16
C17
R13
R14
R15
C15
B+
C18
R26
R25
B+
V7
T6
TO
BANDPASS
AMP.
R27
C32
R28
C33
R29
B+
C19
L1
R17
C20
C22
V5
R18
R20
C21
R19
R21
R22
C23
B+
C26
C27
C24
L2
C25
V6
C28
C29
C31
R23
T5
R24
-5V
C30
TO
QUADRATURE
AMP.
TO Q
DEMODULATOR

A

FIGURE 10


FROM BANDPASS AMP.
T1
BURST AMP.
V1
L1
C1
R1
C2
R2
C3
R3
T2
R4
C4
C5
R5
B+
T3
C6
C7
C8
R6
R11
R7
V2
V3
PHASE DET.
R10
C10
C11
REACT. TUBE
V5
C13
L3
R15
R12
C12
R13
C14
R14
C27
C26
L4
R16
B+
C15
C16
CR1
3.58 MC
R17
3.58 MC OCS.
V6
R18
C17
C18
L5
BUFFER
V4
R19
C19
R20
C20
B+
L6
C21
L2
C22
C23
C24
L7
C25
R-Y DEMOD.
B-Y DEMOD.

B

FIGURE 10

T4E-10

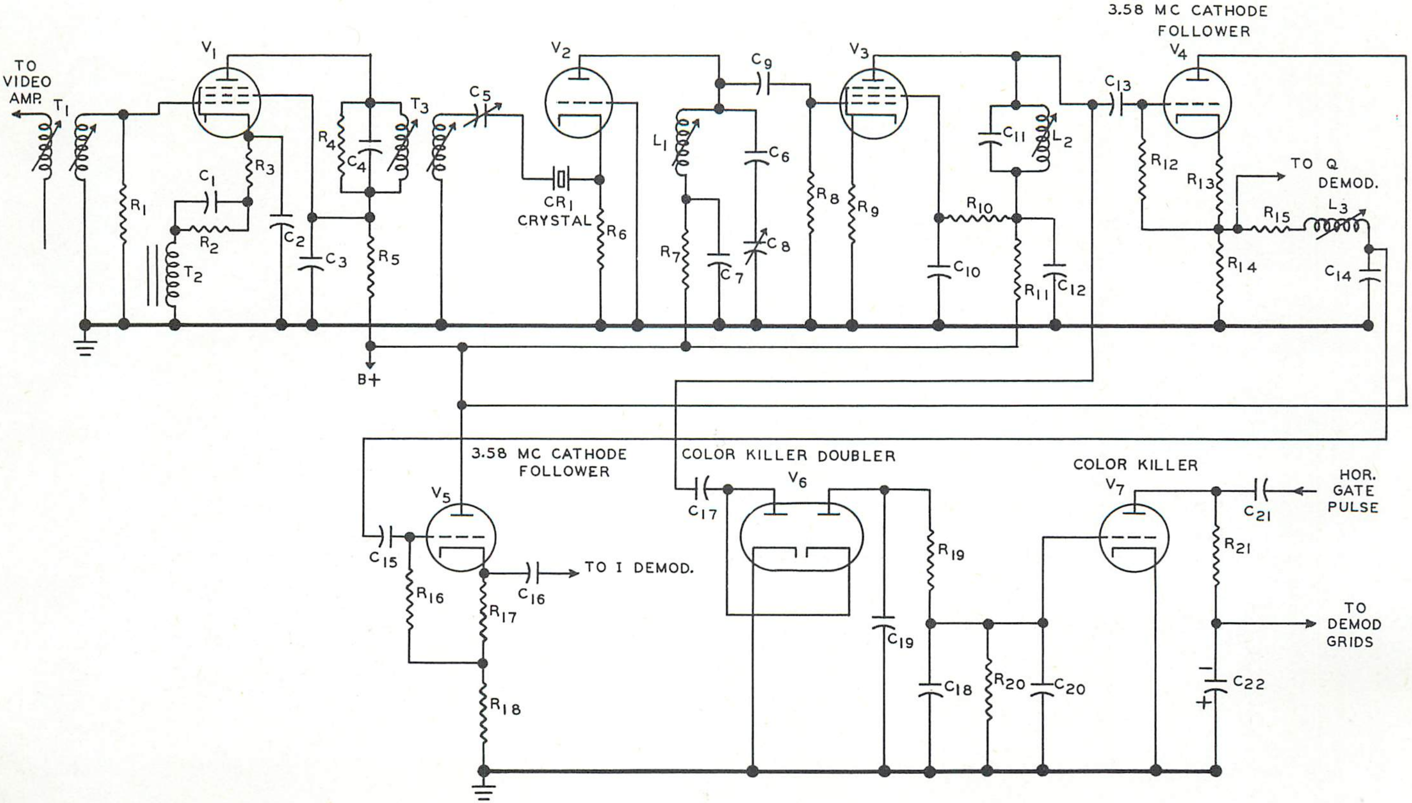


FIGURE 11

FROM OUR *Director's* NOTEBOOK

CLIMBING THE LADDER

The general who leads thousands of troops was once a cadet or a buck private. The president of a large corporation probably was an office boy, junior engineer or a clerk. Practically every man who reaches the top position in his line of work has had to climb the ladder of success.

That's why it's no disgrace to start near the bottom of the ladder. The fact that you have had the benefits of D. T. I.'s training or have had some experience in this field puts you far ahead of the unskilled man, but it doesn't eliminate the need for climbing that ladder of success. It just makes climbing faster and easier.

Now I don't mean you should start by sweeping floors with the hope that you'll be placed in a job for which you are qualified. Set your sights as high as possible—but remember that you can't expect to start in the top spot.

Your employer wants to know that you're able to apply your know-how to his particular problems, and that's where training really pays off. When he finds out you CAN do the job, then he will talk in terms of higher salaries.

The important first step is to GET STARTED on the rungs of the ladder. Then keep climbing as fast as possible.

Yours for success,

W. C. DeVry

DIRECTOR

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